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Art. I.—*The Physiographic History of the Victorian Grampians.*

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Introduction.

The general acceptance by Victorian physiographers of Hart's view, that the Grampian Ranges in Western Victoria owe their topographic form mainly to Tertiary block-faulting, has exercised a profound influence upon interpretations of the physiographic history of other parts of the State. It was chiefly as a result of his studies in the Grampians that Hart himself was led to postulate block-faulting in other sections of the Highlands, and acceptance of the block-faulting idea predisposed physiographers towards invoking faulting in physiographic interpretations, as Fenner admitted in his paper on the Mansfield district (Fenner, 1914, p. 400).

I have recently (1933, 1935) criticised the application of the block-fault hypothesis to the Croydon Lowlands (by Jutson, 1911) and to the Mansfield Basin (by Fenner, 1914), and in this paper I propose to elaborate the view, already presented to an A.N.Z.A.A.S. Excursion in January, 1935, that in the Grampians also, differential erosion of hard and soft rocks, and not Tertiary block-faulting, has been the dominant factor influencing the topographic development.

General Geology.

The Mt. Difficult, Victoria, Serra (also called Sierra), Dundas, Black and other ranges which together constitute the "Grampians" are composed dominantly of massive quartzose sandstones, with subordinate grits, thin-bedded sandstones (both hard and soft), and sandy shales. It has been suggested that these sediments are Lower Carboniferous (see Chapman, 1916), but the evidence for this is not conclusive. Intrusive into the sediments are sills, dykes and stocks of granodiorite, quartz porphyry, and felspar porphyry (Skeats, 1924), as well as granite, and possibly other igneous rock types not specifically recorded. In the larger valleys there are extensive deposits of alluvium, and the southern part of the Victoria Valley has been invaded by a flow of Newer Basalt.

The general structural relations of the formations present in the Grampians were first referred to by Selwyn (1866), who stated that a syncline exists between the Dundas and Black Ranges in the west, and the Victoria and Sierra Ranges in the

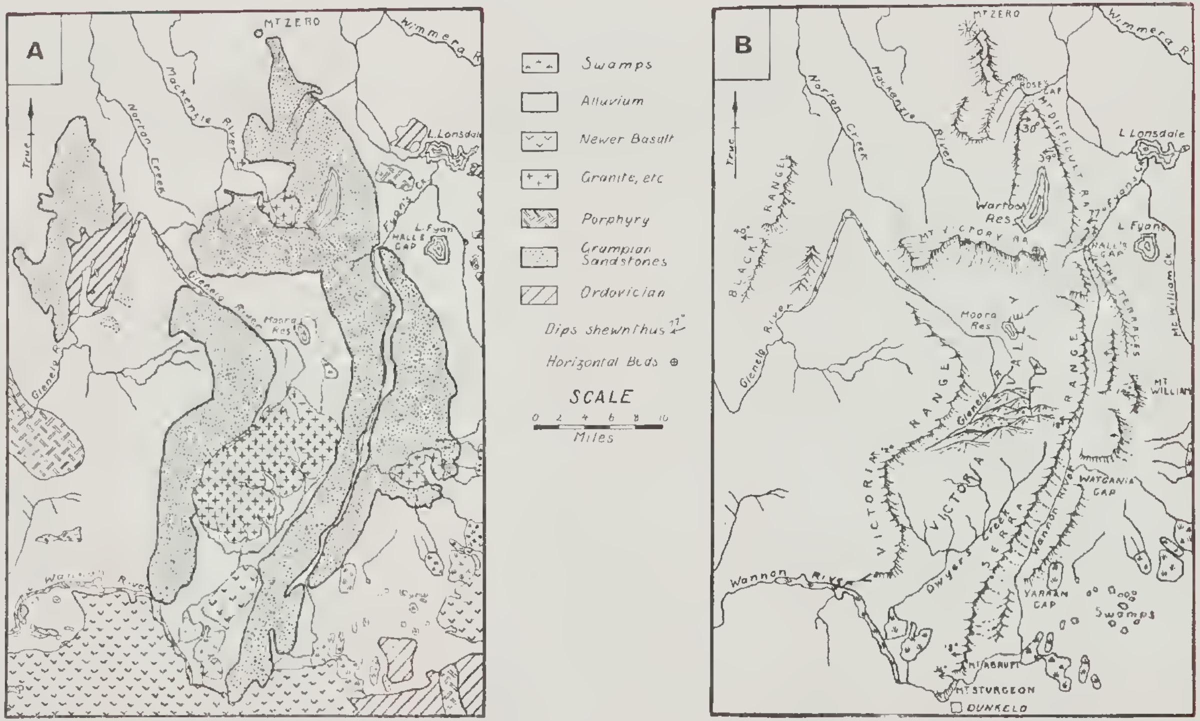

Fig. 1.—A. Geographical map of the Grampian Highlands, Western Victoria. Data from Geological map of Victoria, 1902, issued by the Department of Mines. B. Topographical sketch map of the Grampian Highlands, covering the same area as map A. Data from the Geological Map of Victoria, the Tourist Map of the Hall's Gap District, Krause's Report (1874), and personal observation.

east. Krausé (1874) also mentioned a synclinal structure, the axis of which, he said, appears to run north along the western foot of the Victoria Range to Mount Zero. Gregory (1912, p. 68) described the Grampians as ridges and blocks of old sandstones, in which ridges, folds and faults run north-south. The ridges, he said, are made in part by gentle folds, and in part by faults, but are of the Pennine Type, that is to say, the scarps are erosional features, either fault line scarps or strike ridges (see Avebury, 1906).

Hart, in his paper on the Highlands of Western Victoria (1908), took a different view. He states that the Grampians are to be ascribed to the unequal elevation and tilting of a number of fault blocks, in which the principal faults are approximately meridional, and that the faulting caused a succession of parallel ranges to be formed of the same beds. In support of this he mentions that the earlier geological descriptions give estimates of thickness which are inadequate, unless faulting has occurred, that he had observed a strike fault in Stony Creek, near Hall's Gap, and that, at the Silverband Fall, the stream comes out of a gap in the range and falls to the valley below. As a final qualification, however, he mentions that the faults need not necessarily be altogether of late date, all that is requisite being movement subsequent to the peneplanation, perhaps along old fault lines.

It is solely on the above evidence that the hypothesis of Tertiary block-faulting in the Grampians is based, and Hart's cross section across the Hall's Gap district lends itself to the interpretation later accepted by James (1924, p. 77), that the Grampians are simply fault blocks, in which the escarpments are fault scarps, and the sandstones derive their dip from the tilt of the back slopes of the blocks.

Gregory's remark, that the ranges are of the Pennine Type, has received no subsequent consideration, either critical or appreciative.

Topographic Expression in the Grampians.

The characteristic features, which give to the ranges their topographic expression, are determined in those parts of the Grampians composed of Carboniferous sedimentary rocks by beds of massive resistant sandstones, dipping at different angles in different localities. The erosion of these beds usually results in the development of strike ridges such as the Serra Range, Victoria Range, Mt. Difficult Range, and the Wonderland Range, in which one slope is controlled by the dip (dip slope), and the other (the escarpment) by almost vertical jointing. Where the sandstones dip at high angles, as in the Terraces, a hogback, or if the crest is very sharp, a razorback, results. On the other hand, where the beds are horizontal, or nearly so, erosion results in plateaux with steep bounding escarpments, or in isolated flat-topped hills such as Tower Hill and Castle Hill in the Victoria Valley, which would be termed in America "buttes".

The granitic country in the Victoria Valley is sharply contrasted topographically with the sandstone ridges, the hills there being smoothly rounded.

The present investigation is concerned, however, with the question of the origin of the major topographic features of the Grampians, rather than with the detailed physiography. Most of the observations were made in the Hall's Gap district, but important information was obtained from other parts, concerning the fundamental importance of differential erosion in the development of the topography.

Differential Erosion in the Grampians.

THE WARTOOK BASIN.

The Wartook Reservoir is situated in a topographic basin, which occupies the trough of a syncline or elongated tectonic basin (see Fig. 3), and is bounded on the east, north, and west by a continuous ridge of massive sandstones which forms the outer rim of the basin, and dips inwards towards its centre. The continuity of this ridge, and also the synclinal structure which determines the basin, are best seen in the view to the north from Reed's (Chester's) Lookout, in the Mount Victory Range. Krausé has shown the syncline in his section across the north end of the Grampians, mentioning also the fact that the structure is well shown on the north end of the Mount Difficult Range at Rose's Gap, a locality which I was unable to visit.

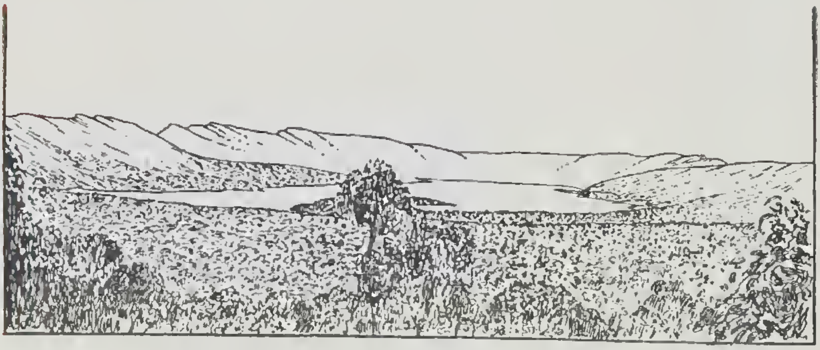

FIG. 2.—View over the basin of the Wartook Reservoir and the Mt. Difficult Range, looking north from Reed's (Chester's) Lookout in the Mt. Victory Range. Note the sandstone ridges dipping inwards towards the synclinal axis, and the continuity of the ridges round the northern end of the basin, due to the southerly pitch of the syncline in the north.

The significance of this excellent example of the structural control of topography, in which the conditions are analogous to those obtaining in parts of the Appalachians, is that, quite clearly, Tertiary or even older faulting can have played no part in its development, except insofar as the whole of the basin, including its immediate environs, may have been uplifted as part of a large fault block, out of which the features described might then have been dissected by differential erosion. For our present purpose, this possibility need not further be discussed, since, in any case, it does not affect the conclusion that differential erosion and geological structure alone have been the determining factors in the development of the basin and its surrounding mountain ridges, which include Mount Difficult (2,657 feet), and which rise to heights of 2,000 feet or more from the plains on the north and north-east. The outer (escarpment) side of the ridge surrounding the basin, which might in its straighter parts have been regarded as a fault scarp, can clearly not be such a feature, because of its sharp curvature round the synclinal axis at the northern end of the basin.

It seems, therefore, that in the case of the Mount Difficult Range and the Wartook Basin, at least, differential erosion, and not Tertiary block-faulting, has been the factor principally concerned in the determination of the topography, and if this be admitted, it follows that a similar amount of differential erosion must have gone on in adjacent parts of the Grampians, since it would be impossible to produce such an amount of erosion in the Wartook district without neighbouring parts having been affected to almost the same extent. Independent evidence of the importance of differential erosion in the southern section of the Grampians is, however, available.

THE VICTORIA VALLEY.

In the country known as the Victoria Valley, between the Victoria Range on the west, and the Serra Range on the east, granitic rocks, very probably post-Lower Carboniferous in age, outcrop, and produce on erosion characteristic rounded hills, very different in aspect from the serrate ridges resulting from erosion of the sandstones. These granitic hills attain an elevation of just under 2,000 feet, which is less than 500 feet below the highest parts of the Victoria Range, and there is no suggestion, either on physiographic or geological grounds, that they owe any part of their elevation above the immediately adjoining Glenelg Valley, to block elevation. Here again, the evidence points clearly to an amount of differential erosion sufficient to account for the existence of the observed topographic features in the granitic terrain, in which the maximum relief is little less than that of the adjacent Victoria and Serra sandstone ridges, which must, because of their contiguity to the granite, have undergone a comparable amount of erosion.

The Structure of the Hall's Gap District.

WONDERLAND RANGE.

As we have seen, Hart's view of the structure of this district is that the parallel ridges of the Mount Difficult Range, the Wonderland Range, and the Terraces (see Fig. 3) are composed of the same sandstone formation, repeated by strike faulting, the valleys between them being regarded as fault angle valleys. Although Hart stated that he observed a nearly vertical strike fault in Stony Creek, near Hall's Gap, I could find no evidence of the presence of any but very minor dislocations in the sandstones in that district. Indeed, in the Stony Creek valley at Venus' Bath, there is the clearest evidence, in an excellent

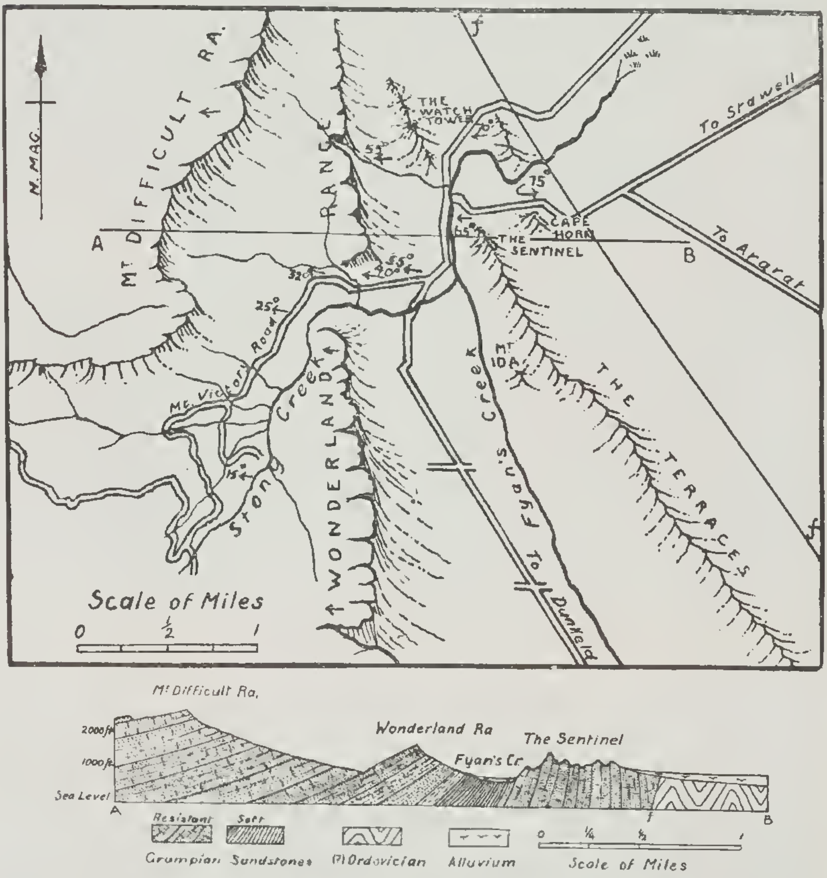

FIG. 3.—Sketch map and geological cross section in the Hall's Gap district. *f.*, probable eastern boundary fault of the Grampians. The dips shown on the map refer to the Grampian sandstones, and the major topographic features are represented as in a bird's eye view.

exposure, that the sandstones of the Wonderland Range dip in natural position underneath those of the escarpment face of the Mount Difficult Range (see Fig. 3), which, it has been shown above, is an erosional feature. The stratigraphical evidence, therefore, shows that the valley of Stony Creek is not tectonic in origin, and the genesis of the Wonderland Range cannot be ascribed to faulting, either Tertiary or older. Indeed, as it is traced northwards, the Wonderland Range decreases in importance as a topographic feature, and finally becomes merely a shoulder on the eastern slopes of the Mount Difficult Range. This is probably caused by thinning of the Wonderland sandstones in the north.

There remain to be considered the Fyan's Creek valley and the easternmost ridge of the Grampians in the Hall's Gap district —the Terraces.

THE TERRACES.

The structure of this range, which extends for about nine miles in a north-north-westerly direction from the northern end of the Mount William Range, is most instructive. It is composed of massive sandstones, dipping either vertically or a few degrees on either side of the vertical, and may be described as a hogback, or even in places a razorback ridge. In a west-east traverse near Hall's Gap, the westerly dip of the beds in the Wonderland Range is found to increase as one traverses eastwards, from 25 deg. to 55 deg., and the most westerly outcrop of the Terraces sandstones shows a dip of 65 deg. in a westerly direction, increasing to the vertical, and finally becoming overturned (dip 105 deg.) on the eastern edge of this range. The most probable explanation of this increase in dip is that the high dips in the Terraces are due to drag along a major fault line, along which the Grampians sandstones were downthrown. The fault must, of course, be very ancient, antedating the Cretaceous peneplain, at least, since the downthrown beds now constitute a mountainous region, and there can therefore be no doubt that the Terraces have not resulted from Tertiary block faulting, but that they are due to the erosion of beds tilted to high angles before Tertiary times. The razorback ridges of the Terraces illustrate clearly the importance of the dissection of geological structures by erosive agents in determining the topography of the Grampians.

It is interesting to note the similarity between the structure of the Terraces and that of the western edge of the belt of Upper Palaeozoic sediments in Eastern Victoria, extending from Mansfield nearly to Bairnsdale. Similar high dips occur along the western edge of this belt of rocks, very probably due to drag along a more or less meridional boundary fault. It would seem that, perhaps in late Palaeozoic times, extensive block faulting occurred in what is now the Central Victorian Highlands, faulting which to-day influences the topography of certain parts of the Highlands to a remarkable degree, especially where hard and soft rocks have been brought into juxtaposition by the fault movements.

Fyan's Creek Valley.

It will now be realized that, bounded as it is on the east and west by strike ridges of resistant rock, the presumption is that Fyan's Creek Valley is itself due to erosion, and not to tectonic movement, but it will be as well to consider the geological facts bearing on the origin of the valley. Data relating to the possible presence of a fault along the valley cannot be obtained in most parts, owing to the extensive deposits of alluvium that cover the valley floor, but to the north of Hall's Gap, the valley narrows considerably, and rises to a saddle west of the Watch Tower. The frequent exposures of sandstone which occur along the small creek leading up to the saddle show no evidence of faulting, and none is to be seen in the saddle itself, where, I think, it might reasonably be expected if a fault were present, owing to the massive nature of the beds that would have been involved.

Fyan's Creek Valley is, however, so much larger than the valley of Stony Creek, that if it is not due to faulting, one would expect to find some other factor which might explain its size. This factor, I believe, is the presence beneath the massive sandstones of the Wonderland Range, of beds which are very much softer and less resistant than those sandstones, viz., closely jointed chocolate and banded micaceous sandstones, which have been exposed in a road cutting about 200 yards along the Mount Victory Road from the junction at Hall's Gap. Some idea of the probable relative resistance to erosion of these soft beds and the massive sandstones may be gained from the fact that the latter, in two tests, showed a crushing strength greater than many granites, viz., 11,200 lbs./sq. ins. and 17,500 lbs./sq. ins., while the former may readily be scratched with the fingernail, and break with ease under the hammer into small fragments.

The full extent of these soft sandstones cannot be demonstrated, owing to the covering of scree and alluvium in the Fyan's Creek valley, but it is significant that, where the soft beds are apparently absent or very thin, as in the northern extension of the valley west of the Watch Tower, the valley is narrow, and where the soft beds have been discovered further to the south, the valley becomes much wider. This suggests that the increasing width of the valley in the south may be correlated with an increased development of the soft beds. In earlier descriptions of the geology of the Grampians, the presence of such beds has not been referred to, owing, I think, to the fact that they are readily eroded and become covered with superficial deposits. I have, however, observed sandy shales at the saddle traversed by the road at the southern end of the Victoria Valley, and soft sandstones above the Silverband Falls along the road to Mount Victory, south of Hall's Gap.

Summary and Conclusion.

The arguments presented above have been directed to the demonstration of the following points:—Firstly, that differential erosion is the only process which is adequate to produce certain of the major topographic features of the Grampians; secondly, that in the Hall's Gap district, geological evidences of faulting between the three parallel ridges constituting the Mount Difficult Range, Wonderland Range, and the Terraces are absent; thirdly, that these ranges are separated by valleys which have been excavated by stream erosion, aided, in the case of the Fyan's Creek valley, by the presence of soft beds beneath the sandstones of the Wonderland Range; and fourthly, that the eastern boundary of the Grampians in the Hall's Gap district is probably marked by an ancient fault line, along which the Grampians sandstones were depressed, drag along this fault plane having caused the high dips in the sandstones of the Terraces. I conclude, therefore, that, as Gregory considered, the Grampians are highlands of the Pennine type, and now stand above the surrounding country because they are composed dominantly of relatively very resistant rocks. The sandstone ridges in the Grampians are strike ridges, and the valleys have been excavated by stream erosion, and are not tectonic in origin.

I do not propose to enter at this time into a discussion of the development of the river system in the Grampians, or of the nature of the uplift, which, as part of the Western Highlands of Victoria, the Grampians must have undergone since the last extensive peneplanation, which I believe took place in Victoria in Upper Cretaceous times (Hills, 1933). The nature of the surface at the time of peneplanation, and the type of movement which took place, as well as the geological structure, have all to be considered in any discussion of the development of the stream system, and adequate data concerning these have not yet been accumulated. However, the drainage pattern in the Grampians, and the relations between the streams and the geological structures are, so far as my knowledge goes, in accord with the origin of the Grampians topography outlined above, and are not comparable with the drainage of block-faulted regions in other parts of the world. The Silverband Falls, which Hart considered indicate late movement along a fault line, are, in my opinion, determined by the presence of a resistant sandstone formation crossing the valley of Dairy Creek.

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